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Propulsion and Auxiliary Systems Department
Research and Development Report

USER'S SUPPLEMENT TO MIL-STD-740-2 MODIFIED FOR MEASUREMENTS TO 20 KHZ

by
D. Maxwell
R. W. Miller

DTRC/PAS-89-28 User's Supplement to MIL-STD-740-2 Modified for Measurements to 20 KHz

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This supplement to MIL-STD-740-2 is specifically diected to provide guidance for performing structureborne vibratory acceleration measurements to 20 KHz. This supplement modifies the standard in those areas where changes are necessary to make high frequency measurements. This supplement also provides guidance in those areas where past experience has shown that many naval shipboard equipment manufacturers have had difficulty in interpreting the requirements of the standard.

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ABSTRACT

This supplement to MIL-STD-740-2 is specifically directed to provide guidance for performing structureborne vibratory acceleration measurements to 20 KHz. This supplement modifies the standard in those areas where changes are necessary to make high frequency measurements. This supplement also provides guidance in those areas where past experience has shown that many naval shipboard equipment manufacturers have had difficulty in interpreting the requirements of the standard.

INTRODUCTION

MIL-STD-740-2 specifies acceptable instrumentation and procedures for the measurement and analysis of structureborne vibratory acceleration generated by naval shipboard equipment. The standard also specifies acceptance criteria for structureborne vibratory acceleration levels; however, equipment purchase specifications may include criteria which supersede those defined in MIL-STD-740-2. The referenced documents listed in the standard also describe acceptable instrumentation and measurement procedures. This supplement discusses some of the requirements given in MIL-STD-740-2 and is intended to provide further guidance for performing structureborne noise evaluation of naval shipboard equipment. The equipment purchase specification should provide the appropriate implementation guidance in accordance with paragraph 6.3 of MIL-STD-740-2.

This supplement is also intended to provide further guidance for performing structureborne noise evaluation over an extended frequency range. In particular, the ability to extend reliable measurements from 10 KHZ to 20 KHz is addressed. The items that significantly affect the ability to achieve these measurements are the accelerometer, preamplifier, and the method of attachment.

APPROACH

The basic method used to determine equipment acceptance is the measurement of the structureborne vibratory acceleration level (L_a) in decibels (dB) at specific locations on the equipment. Unless otherwise specified, equipment is considered to have acceptable structureborne vibratory acceleration levels when none of the levels measured at the designated locations exceed the applicable structureborne acceptance criteria specified in the procurement package. Figure (1) is an example of an acceptance criteria. Procurement documentation may also invoke maximum permissible structureborne levels at specified frequencies such as

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rotational, twice electrical line frequency, slot frequency, gear mesh frequency, etc., as indicated in paragraph 6.3 of MIL-STD-740-2.

VENDORS PROPOSED EQUIPMENT EVALUATION PLAN

To ensure that acceptable evaluation procedures are performed, a detailed description of the vendor's proposed evaluation procedure is often required to be submitted to the procurement activity for acceptance at least six weeks before the evaluation is to be conducted. See paragraphs 4.2 and 6.4. The items to be included in the evaluation plan are given in detail in Data Item Description No. DI-HFAC-80273.

MEASUREMENT-POINT LOCATION

Unless otherwise specified, measurements to determine acceptability are required on all equipment as stated in paragraph 5.3.1 of MIL-STD-740-2. Specific measurement points should be detailed in the procurement package. Figure (2) of this supplement illustrates typical measurement-point locations with the accelerometer mounted on the equipment side of the resilient mount. Measurements are to be made at each location in three mutually perpendicular directions. This may be accomplished by attaching three accelerometers in the form of a orthogonal arrangement as illustrated in figure (3) of this supplement. For a flanged unit, the measurement-point locations would be at resilient mountings on diametrically opposite sides of the flange. See figure (4). The method of attaching accelerometer mounting blocks to the equipment will be specified in the equipment procurement package. Usually the mounting block will be required to be cast as an integral part of the equipment or attached by full penetration welding.

In addition to the above measurements required to determine equipment acceptability, vibratory acceleration measurements must be made of all rotating equipment for the sole purpose of guiding maintenance. The three measurement-point locations used for this purpose are described in paragraph 5.3.2 of MIL-STD-740-2. Specifically, for all fans and motor-driven pumps, accelerometers are to be oriented perpendicular to the machine's rotating shaft, one at each end of the auxiliary machine. These locations are designated "1" and "2". In addition to locations 1 and 2, for all motor-generator sets and motor-driven compressors one accelerometer must be oriented axial to the machine's rotating shaft. This location is designated as "3". The measurement-point locations used for guiding maintenance are illustrated in figures (5), (6) and (7).

ACCELEROMETER ATTACHMENT

PREPARATION

The surfaces on which accelerometers are attached should be prepared as specified by the procurement document or if not specified, the surfaces should be prepared as required by MIL-STD-740-2. That is, the surfaces to which the accelerometers are attached should be flat within 700 microinches rms or better and the surface finish should be 125 microinches or better. Holes for mounting studs should be drilled perpendicular to the surface within 1 degree or better and should be tapped to a depth suitable to accommodate the proper stud for the accelerometer without bottoming in either the accelerometer or the mounting hole. See figure (8).

ATTACHMENT

Unless otherwise specified, the required method of attachment is to directly stud mount the accelerometer to the surface where the measurements are to be taken. Use silicon grease (preferred) or other light oil or grease between the accelerometer and the mating surface. Tighten down the accelerometer using the torque specified by the stud manufacturer. See figure (9).

> Note: Make sure that this mounting does not cause a ground loop which will manifest itself in increasing the apparent spectrum level at electrically related frequencies. In multiple channel systems, ie., more than one accelerometer mounted and electrically connected, ground loops are almost a certainty.

If direct stud mounting proves impractical, ie., if ground loops occur, then alternative methods of attachment must be used. Several alternative methods are listed below.

(a) Mount as above but replace the standard stud with an anodized aluminum stud having a shoulder near the center of the threaded length. See figure (10). It also is necessary to check the electrical isolation of the accelerometer case from the machinery component or block after mounting since the anodized surface of the stud is easily scratched thus negating its insulating quality. If electrically shorted, replace the stud with a new one and discard the old one. An ohmmeter (multimeter) may be used for this check. The resistance should be at least 10 Megohms, essentially an open circuit.

(b) Another method of attachment involves use of an insulated stud. This type of insulated stud consists of two parts which are bonded together with a non-conductive cement (epoxy). See figure (11). Laboratory experience suggests that this type of insulated stud is prone to bond failure after frequent use. Such failures are difficult to detect by inspection of the stud and yet affect the data often causing the signal level to be high. Such failures have only been found while calibrating an accelerometer with the stud by noting a difference in the frequency response from that normally found. When using any stud, use silicon grease or light oil between all mating surfaces and tighten using the stud manufacturers' recommended torque. Note: While problems can occur, these studs have been used successfully for many years. To minimize this type problem, calibrate the accelerometer with the stud to be used in the measurements.

(c) Mount the accelerometer by using a cementable stud. In this method, the stud is torqued to the accelerometer using the torque specified by the stud manufacturer and with silicone grease or light oil between the mating surfaces. The exposed shoulder on the cementable stud is then cemented to the mounting surface using one of the recommended cements/bonding agents. See figure (12). It is extremely important to follow the surface preparation requirements given with the cements in order to ensure a good bond. It is again necessary to check for electrical isolation.

(d) It is also acceptable to cement the accelerometer directly to the measurement location. The same care in surface preparation prior cementing must be taken and one must again check for electrical isolation. A multimeter may be used for this check.

SURFACE PREPARATION FOR CEMENTING

Quick-set epoxies require only a minimum of surface preparation, however, lack of surface preparation is the most common cause of adhesive failure. The surfaces must be made free of organic contaminants by degreasing. Paints and other coatings should be removed and the surface roughened by sanding, then the exposed surfaces should again be cleaned. Note that sanding is a departure from the normal surface finish requirements and is necessary for good bonding of epoxy-type adhesives. The adhesive should be applied as soon as possible after surface preparation, especially in environments where airborne contaminants are present. To test the metal for cleanliness, apply a drop of water to the surface; if it spreads on the surface is sufficiently clean; if it beads it is not clean enough. Be sure the surface is dry before applying the adhesive.

Cyanoacrylates require that, in addition to being clean, with the pai and other coating removed, the mating surfaces must be flat wi in 700 microinches rms or better and have a surface finish of 125 microinches or better. Some acceptable cements are listed in Table 1.

CAUTION - Follow manufacturers' recommendations for safe handling and use of adhesives and all materials used in surface preparation.

INSTRUMENTATION

A block diagram of a typical measurement system used to determine structureborne vibratory acceleration levels is shown in figure (13). The instrumentation used for the measurement and analysis of structureborne vibration must be in accordance with paragraphs 5.2.2.1 and 5.2.2.2 of MIL-STD-740-2. The frequency range shall include the 10 Hz through the 20 KHz one-third octave bands. The recorder used with the system must provide a permanent reproducible copy conforming to paragraph 4.4.3 of MIL-STD-740-2, and the complete system shall have a flat response within plus or minus 2 dB over the frequency range specified.

The instrumentation package required to make structureborne noise measurements under MIL-STD-740-2 includes the following instruments:

ACCELEROMETERS
PREAMPLIFIERS
SIGNAL CONDITIONING AMPLIFIERS
OSCILLOSCOPE
SPECTRUM ANALYZER
PLOTTER
VIBRATION CALIBRATOR
SIGNAL GENERATOR
ELECTRONIC VOLTMETER

ACCELEROMETER CHARACTERISTICS

To meet the requirement of taking structureborne noise measurements at frequencies up to 20 KHz within the acceptable tolerance of MIL-STD-740-2, extreme care in accelerometer selection must be taken. The accelerometer to be used in the structureborne noise measurement system must have a flat response within plus or minus 2 dB over the frequency range of interest. Many accelerometers available are not suited for noise measurements to 20 KHz by virtue of their relatively low mounted resonant frequency. The mounted resonant frequency is the natural frequency of the accelerometer seismic mass-spring system and this frequency may be used to define the useful upper frequency limit of an accelerometer. As a general rule the upper frequency limit of an accelerometer is considered to be one-third of its mounted resonant frequency for less than 1 dB error, assuming that the accelerometer is properly coupled to the mounting location. The higher the mounted resonant frequency, the wider the operating frequency range. This implies that to be suitable for high frequency applications to 20 KHz the accelerometer should have a mounted resonant frequency of approximately 60 KHz or higher. There are exceptions, some accelerometers such as those with built-in electronics meet the response characteristics even though their resonant frequency is much lower than 60 KHz.

It is equally important to make certain that the accelerometer selected has adequate sensitivity to provide acceptable signal-to-noise ratios when measuring the structureborne noise levels required by the equipment acceptance criteria. To obtain reasonably good accuracy in the measurement, the background noise level or noise floor should be at least 10 dB below the structureborne noise levels to be measured ie., the specified acceptance criteria for the equipment. This background noise level is a function of both the sensitivity of the accelerometer at the input of the preamplifier as well as the preamplifier's internal noise spectrum.

Accelerometers are available which are adequate to cover the entire frequency range of interest. In a few exceptional cases where extreme environmental conditions or particularly restrictive acceptance criteria must be met, it may be necessary to use two accelerometers to achieve acceptable signal-to-noise ratios. The need for two accelerometers should be determined considering the specified acceptance criteria, instrumentation characteristics and environmental conditions.

As an example, with an acceptance criteria of 40 dB across the entire frequency range and the MIL-STD-740-2 requirement that the background level be at least 10 dB below the signal level being measured, the maximum acceptable background is 30 dB or less. This means that the noise level at the preamplifier output when referred to the input can not exceed 30 dB. This level in volts is a

function of the sensitivity of the accelerometer at the input of the preamplifier as well as its internal noise spectrum. The complete measurement system must also be flat within plus or minus 2 dB.

To meet the conditions above, the accelerometer used would need to have the following basic characteristics.

Basic Stud Mounted resonance: Approximately 60 KHz or higher
Sensitivity (including cable): > 30 mV/g

If such an accelerometer is unavailable, then two accelerometers could be used. One covering the low frequency range and another covering the upper frequency range. The ranges should overlap.

The low frequency range accelerometer should have the following characteristics.

Mounted resonance: > 30 KHz
Sensitivity (incl. cable): > 30 mV/g

The high frequency accelerometer should have the following characteristics.

Mounted resonance: Approximately 60 KHz or higher
Sensitivity (incl. cable): > 10 mV/g

Figure 14 shows the noise levels associated with two accelerometer-preamplifier combinations which meet the above characteristics. One should note that if the structureborne noise acceptance criteria was higher, say 50 dB, then only one accelerometer would be needed to meet the measurement requirements.

While the above discussion applies to accelerometers used in conjunction with voltage preamplifiers, similar problems must also be addressed when using charge preamplifiers.

If environmental factors allow its use, an accelerometer with a built-in preamplifier (charge or voltage) should be considered. However, sensitivity, resonant frequency, and internal noise are factors that still must be considered.

PREAMPLIFIERS

After the accelerometer, the characteristics of which have been discussed, has been selected, the most important instrumentation is the preamplifier. The preamplifier may be either a charge or voltage type. It may be either a separate device or be contained within the accelerometer housing. In some cases its function is contained as the input stage of the signal conditioning amplifier. Which type amplifier to use depends on whether one wants to detect voltage or charge as the output from the accelerometer.

VOLTAGE PREAMPLIFIERS

The output of a voltage preamplifier is proportional to the voltage input. Therefore the accelerometer is considered a voltage source when used with this type preamplifier. Under this operation the voltage sensitivity at the input of the preamplifier is reduced by the ratio of the accelerometer capacitance to the total capacitance. This requires that the system be recalibrated any time the cable is changed. Thus the longer the cable the lower the voltage sensitivity resulting in loss of signal to noise ratio. This fact dictates the need to keep the cable between the accelerometer and the preamplifier as short as possible for very low level measurements. The input resistance of the preamplifier affects its low frequency performance. The higher the input resistance the better the low frequency performance. To obtain good performance, select a preamplifier having an input resistance on the order of 1000 Megohms. Be sure that the preamplifier has very low internally generated noise and that is has the capability to drive the output cable as desired over the frequency range required. The dynamic range capability of the preamplifier should exceed the dynamic range of the measurement signal.

CHARGE PREAMPLIFIERS

The output of a charge preamplifier is a voltage proportional to the charge input. The accelerometer is considered a charge source when used with this type preamplifier. The sensitivity of an accelerometer/charge preamplifier system is not affected by the input capacitance and thus unaffected by the input cable length. The voltage out is proportional to the ratio of the charge generated to the feedback capacitance in the preamplifier. However, increases in the input capacitance result in an increase in the input noise which is affected by cable length. Thus the longer the cable the lower the signal to noise ratio. Thus the cable between the preamplifier and accelerometer should be kept to a minimum. The feedback capacitance also affects the noise. The higher the capacitance the higher the noise. The higher the feedback capacitance the lower the gain, thus select a high gain preamplifier. The input resistance also affects the noise, therefore the input resistance of the preamplifier should be in the order of 1000 Megohms. The low frequency performance is determined by the time constant formed by the feedback circuit in the preamplifier. Select a preamplifier having suitable low frequency response. The dynamic range of the preamplifier should exceed the dynamic range of the signal.

INTEGRAL AMPLIFIERS/LINE DRIVERS

An integral amplifier usually consists of the input stage of a voltage or charge amplifier contained within the accelerometer housing. A line driver is a separate device usually the input stage of a charge amplifier which is mounted directly to an accelerometer or placed nearby. In some cases these preamplifiers have gain which increases the signal level immediately as well as providing a low impedance to drive the output cables. These systems require a power supply to which they are connected by a two conductor cable. This cable carries both power and signal. Note that there are both constant voltage and constant current systems and they are not interchangeable. These systems are less sensitive to ground loop and cable generated noises. However it is still important to use high quality low noise shielded cable in low level measurement situations. Careful attention to specifications is required when selecting this type system to insure that it meets all the conditions necessary for low level wide frequency range measurements.

Regardless of the type of preamplifier chosen to be used, the following statement applies.

WHEN MAKING LOW LEVEL STRUCTUREBORNE NOISE MEASUREMENTS, GET THE SIGNAL LEVEL AS HIGH AS PRACTICAL AS SOON AS POSSIBLE.

REMAINING INSTRUMENTATION

The remaining instrumentation is not as critical but is required for this application. Most off-the-shelf equipment is satisfactory. The signal conditioning amplifier is usually required to get the signal level to an acceptable level to input to the spectrum analyzer and/or a magnetic tape recorder if used. The use of the other instruments is obvious.

CALIBRATION OF INSTRUMENTATION

A laboratory calibration is required of all vibration measuring instrument systems within 12 months prior to each use as stated in paragraph 5.7.1 of MIL-STD-740-2. In addition, all instrumentation used in calibrating the measurement system shall have a calibration within six months prior to each use traceable to the National Institute for Standards and Technology (formerly named The National Bureau of Standards). The laboratory calibration of the measurement system and accelerometer shall be accurate within plus or minus 1 dB. Accelerometers may be calibrated by one of the methods specified in ANSI S2.2. The comparison method of accelerometer calibration is illustrated in figure (15) of this supplement. To minimize error in high frequency vibration measurement, the accelerometer and stud combination should be calibrated and used as a matched set over the frequency range of interest.

Measurement system electrical calibration of frequency response and linearity are described in paragraphs 5.7.2.1 and 5.7.2.2 of MIL-STD-740-2. Figures (16), (17) and (18) of this supplement illustrate how the calibrating voltage is inserted in series with the accelerometer to provide a simulated accelerometer output. Known voltages at known frequencies are then introduced into the system and recorded to determine the frequency response and linearity of the system under conditions which closely simulate the actual measurement situation. Measurement standards must be kept under controlled conditions in the manufacturer's laboratory and used only for calibrating the measurement system.

Where machinery evaluations are performed in the field, an electrical test of the measurement system (exclusive of the accelerometer) must be made each work shift prior to making measurements. This is accomplished by introducing a known voltage directly into the system and recording the level at stated frequencies as described in paragraph 5.7.3 of MIL-STD-740-2. In addition to the electrical test, the total vibration measuring system (including the accelerometer) must be evaluated by true dynamic calibration for a least one frequency. This may be accomplished by attaching the accelerometer to a small field calibrator as shown in figure (19). Various models of field calibrators are available commercially which are capable of producing 1 g vibration at a single fixed frequency. Examples are GenRad Model 1557A, Brüel & Kjaer Model 4294, and PCB Model 394A05. The instrumentation is set up as in normal operation, with the exception that the accelerometer is mounted on the calibrator. By observing the response of the components of the measurement system, an operational verification may be made of the entire system. Since the vibration level is known, a calibration of the system is obtained for a particular frequency. Field calibrations must be accurate within plus or minus 2 dB.

MEASUREMENT PROCEDURES

1. Select the measurement-point locations on the equipment for mounting accelerometers. These will be specified in the procurement package.

2. Attach accelerometers to the equipment at all of the selected measurement-point locations. Accelerometers must be oriented such that structureborne vibratory acceleration levels may be measured in three mutually perpendicular directions as specified in paragraph 5.2.1.1 of MIL-STD-740-2.

3. One-third octave band measurements shall be made in the three mutually perpendicular directions at the locations specified by the procurement package. The complete frequency range of interest shall be analyzed and recorded using instruments equivalent to those specified in paragraph 5.2.2.1 of MIL-STD-740-2. Measurement location and direction, and recorded levels shall be clearly identified and referenced on the graphic level recording. Scale factors required to convert recorded levels to vibratory acceleration levels (L_a) shall be indicated on the data. Equipment operating conditions shall also be noted on the data sheets. Ambient levels must also be recorded and reported.

4. When narrowband measurements are required by the ordering activity, they shall be made in the three mutually perpendicular directions at the locations specified by the procurement document. Narrowband analysis shall be performed using the minimum analysis bandwidth limits invoked by the equipment purchase specification. The complete frequency range of interest shall be analyzed and recorded using instruments equivalent to those specified in paragraph 5.2.2.2 of MIL-STD-740-2. Ambient levels shall also be measured and recorded. Accelerometer locations, orientation and measured levels shall be clearly identified and referenced on the data sheets. Equipment operating conditions shall also be noted. The scale factors required to convert recorded levels to acceleration levels (L_a) shall be indicated on the data as well as the bandwidth used for the analysis.

5. For both one-third octave band and narrowband measurements, the data must be acquired having a minimum time bandwidth product of 25 as required by paragraph 5.2.2.2 of MIL-STD-740-2. The time bandwidth product is also known as the Bandwidth Time (BT) product. Paragraph 5.2.2.2 begins with the following statement. "The product of the analysis bandwidth in Hertz times the total sample time in seconds shall be at least 25 at all frequencies." The purpose of specifying the BT product is to assure accuracy of measured values. The minimum value of 25, which is specified above was selected to provide a 95% probability of a measurement being within 2 dB of the real value.

For constant percentage bandwidth filters which include parallel analog filters and parallel digital filters, the BT product is as follows:

BT = (Analysis Filter 3 dB point Bandwidth)(Integration Time)

With the development of modern analysis using digital techniques (DFT/FFT), there is a choice of synthesized filters (windows) with different characteristics in terms of bandwidth, band-pass ripple, and selectivity. This permits the data analyst to select the optimum filter (window) shape for a given application. Commonly used window types include rectangular, Hanning, Hamming, Kaiser-Besel, and flat top. The preferred window type is dependent upon the nature of the signal being analyzed. For most applications involving the measurement of vibratory acceleration according to MIL-STD-740-2, it is recommended to use the Hanning window. For constant bandwidth digital systems, the BT product may be determined as shown below.

$$\text{Filter Bandwidth} = \frac{\text{(Analysis Frequency Range)(Window Weighing Factor)}}{\text{Number of Frequency Lines}}$$

Where:
Number of frequency lines = 1/2 of the number of FFT transform points
Window weighing factor = A value based on the analysis window used

$$\text{Time} = \frac{\text{(2)(Number of Frequency Lines)(Number of Ensembles)}}{\text{Sampling Frequency}}$$

Where:
Ensembles = Commonly referred to as averages
Sampling Frequency = A number which is analyzer dependent (Obtain from analyzer specifications)

$$\text{BT} = \frac{\text{(Analysis Frequency Range)(2)(Window Weighing Factor)(Number of Ensembles)}}{\text{Sampling Frequency}}$$

Where:
Window = Selected by analyst (or obtained from analyzer specifications)
Weighing Factor = Selected from table below

Window	Weighing Factor
Hanning	1.44
Hamming	1.30
Kaiser-Besel	1.79
Flat-top	3.72
Rectangular	0.89

REPORTING STANDARDS

Uniformity in reporting of data is necessary to facilitate mutual understanding and effective comparison and analysis of data from various sources. It is mandatory that the applicable reference quantity be indicated on each table, figure, and graph, and at least once in the text. The reference quantity for structureborne vibratory acceleration level (L_a) is one micro g_n ($1\mu g_n$) or approximately ten micrometers per second squared ($10\mu m/s^2$) as given in paragraphs 3.2.3 and 3.2.4 of MIL-STD-740-2. The reference quantity may be introduced by "re:" which indicates that the level reported is "with reference to." For example, the one-third octave 100 Hz band level re: $1\mu g_n$ ($10\mu m/s^2$) is 85 dB.

The bandwidth of the measurement bands shall be reported together with the measured levels. Normal procedure for reporting measured levels shall include the bandwidth and the band-center frequency with the level. For example, the one-third octave 100 Hz band level was 85 dB; the 10 Hz bandwidth 100 Hz band level was 85 dB; or the 6 percent bandwidth 100 Hz band level was 85 dB.

The mandatory format for all plots of data in which a level in decibels is plotted against frequency on a logarithmic scale shall be made on graphs in which a factor of ten in frequency is equal in length to 25 dB (preferred) or 50 dB. Where the bandwidth of analysis is one-third octave or larger, one factor of ten in frequency shall preferably be 50 mm in length. A sample format is shown in figure (20).

DETAILED REPORT TO BE SUBMITTED AFTER EVALUATION

A detailed equipment structureborne vibratory acceleration measurement test report for the equipment measured under each contract or order is often required to be submitted to the procuring activity. See paragraphs 5.10 and 6.4 of MIL-STD-740-2. Data Item Description No. DI-HFAC-80274 describes in detail the items to be included in the report. Much of the information to be submitted in this report is the same as that submitted earlier under the "Vendor's Proposed Equipment Evaluation Plan," paragraph 4.2. Data Item Description No. DT-HFAC-80273 describes in detail the items to be included in that plan. Tabular and graphic records of the measured ambient and equipment structureborne acceleration levels must be included in the report. Equipment vibration sources and their frequencies of excitation (rotational, gear tooth contact, etc.) must be identified and included. Comparison of the measured structureborne acceleration levels with the specified acceptance levels is also required in the report.

ADDITIONAL READING

Since structureborne vibration problems vary widely, the material presented herein must be considered general in nature and for guidance only. To further pursue the material presented it is suggested that the following publications be read. They contain excellent relevant material.

Shock and Vibration Measurement Technology, p/n 29005, available from ENDEVCO

Piezoelectric Accelerometers and Vibration Preamplifiers, by M. Serridge and T. R. Licht, October 1986, available from Brüel & Kjaer

General Guide to ICP Instrumentation, G0001, available from PCB Piezotronics, Inc.

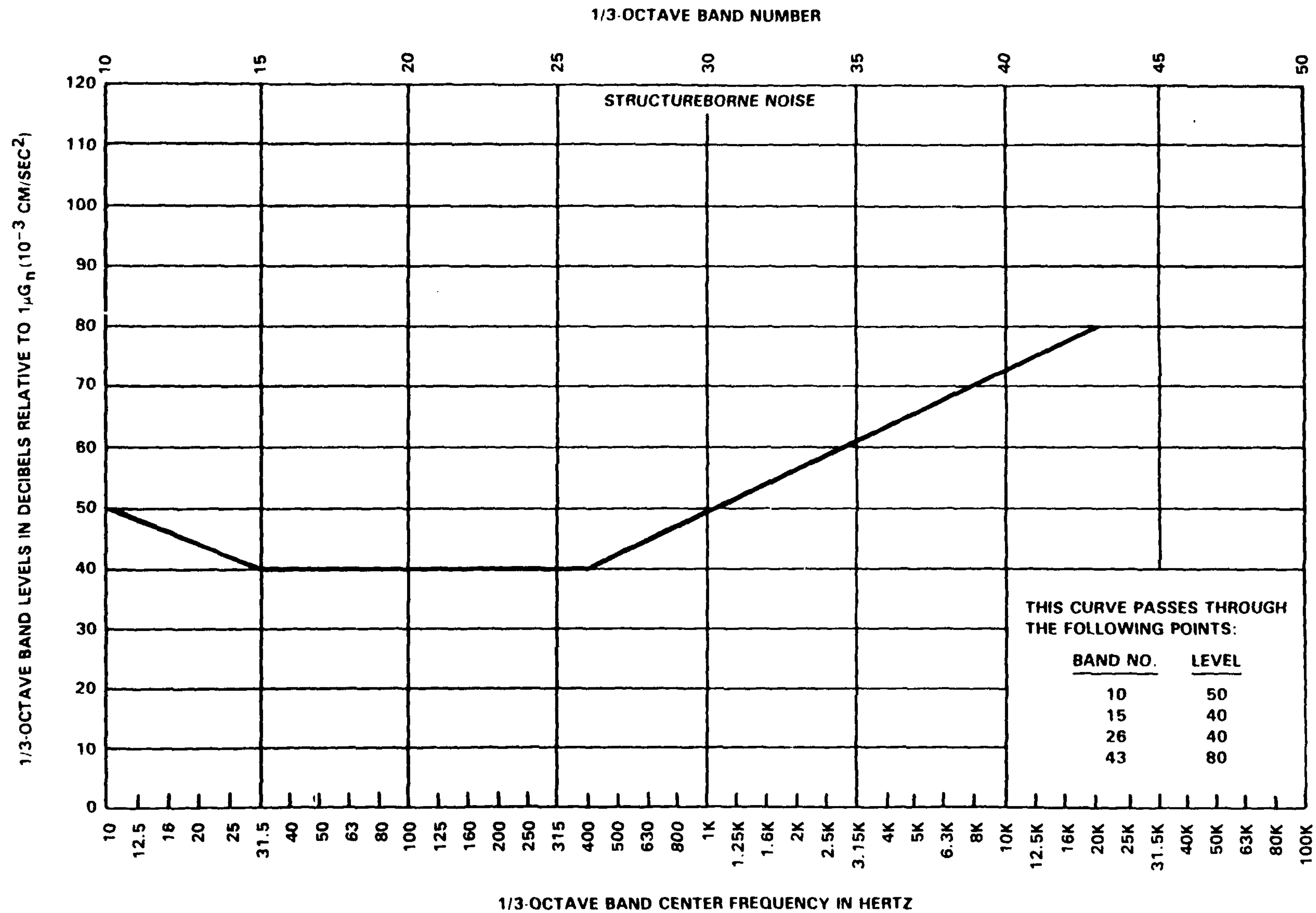


Fig. 1. Example structureborne acceptance criteria.

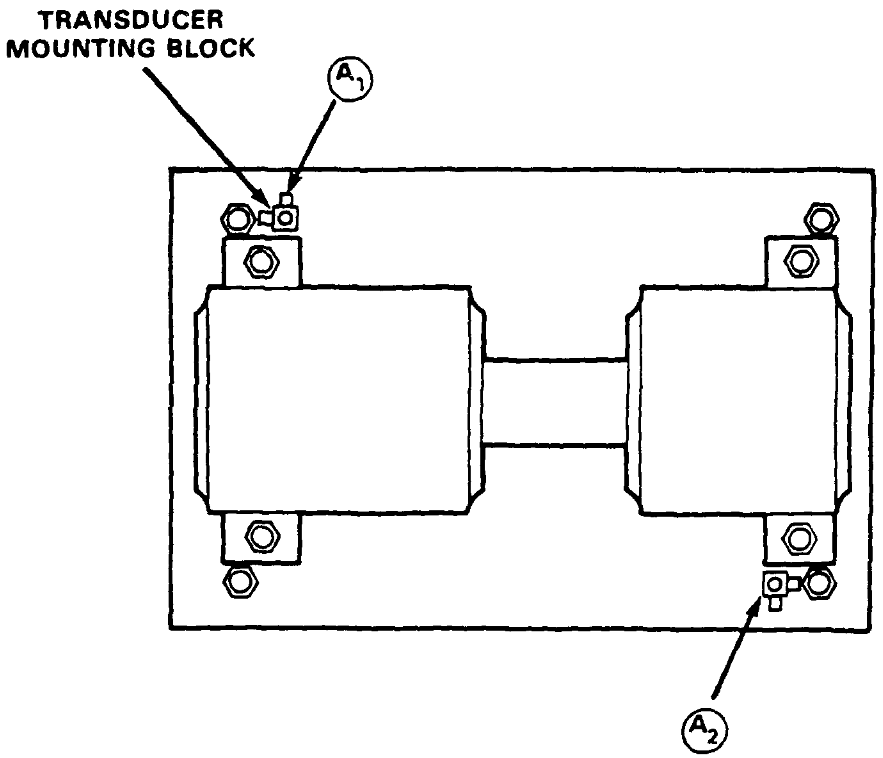


Fig. 2A. Top view showing measurement-point locations indicated by A_1 AND A_2.

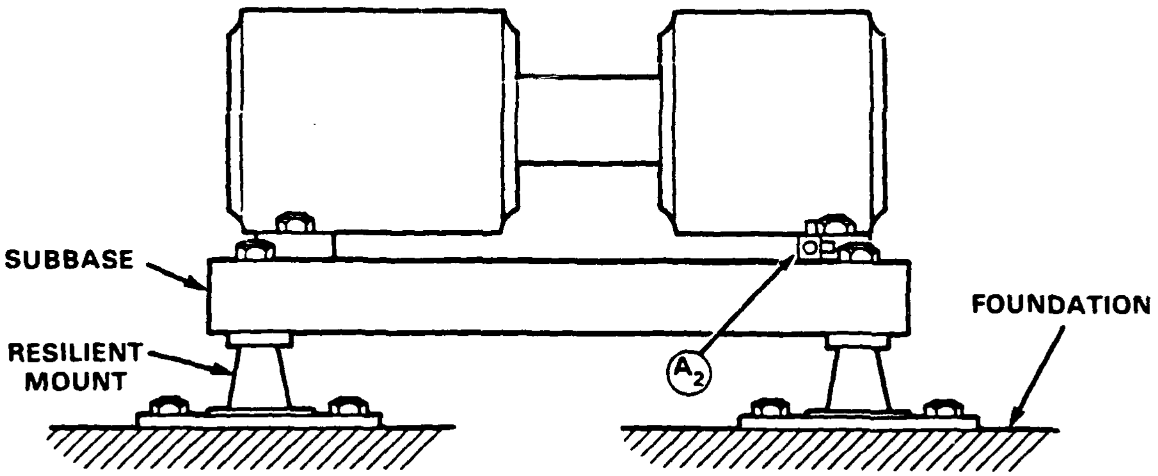


Fig. 2B. Side view.

Fig. 2 Example of a motor-driven unit.

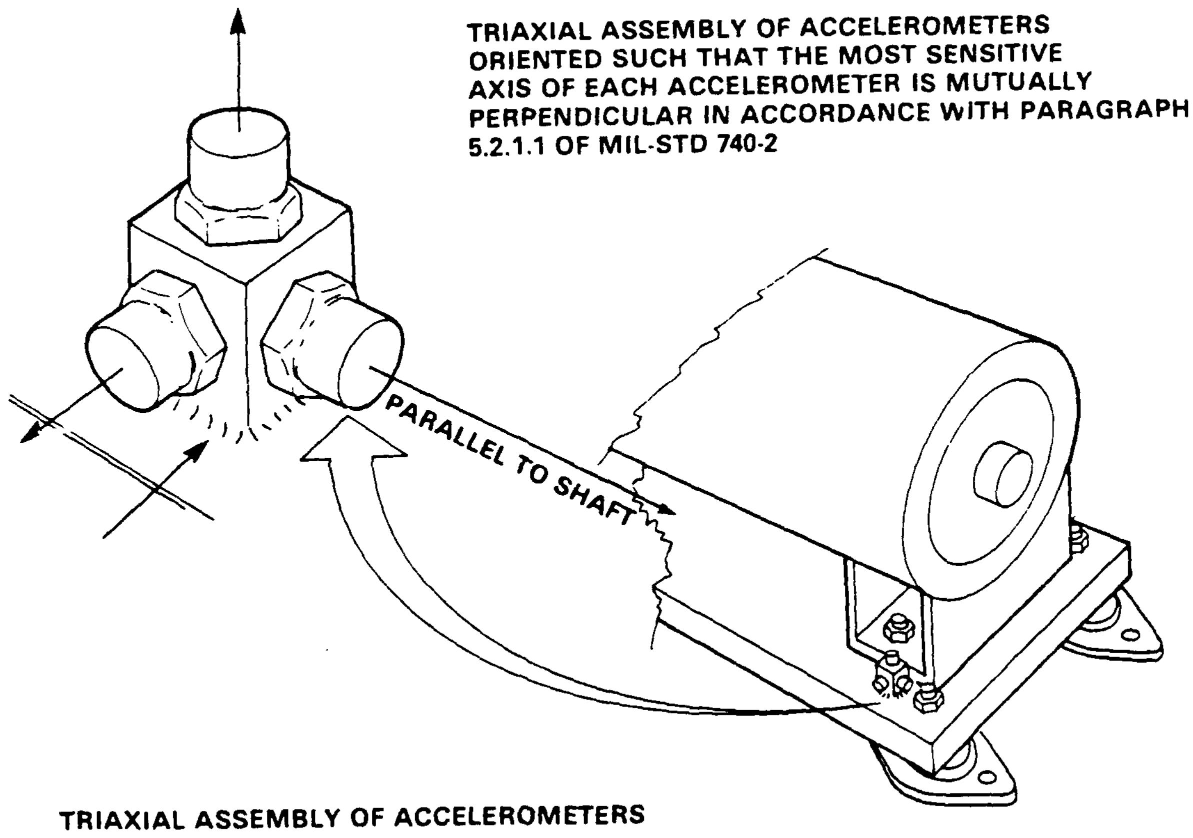
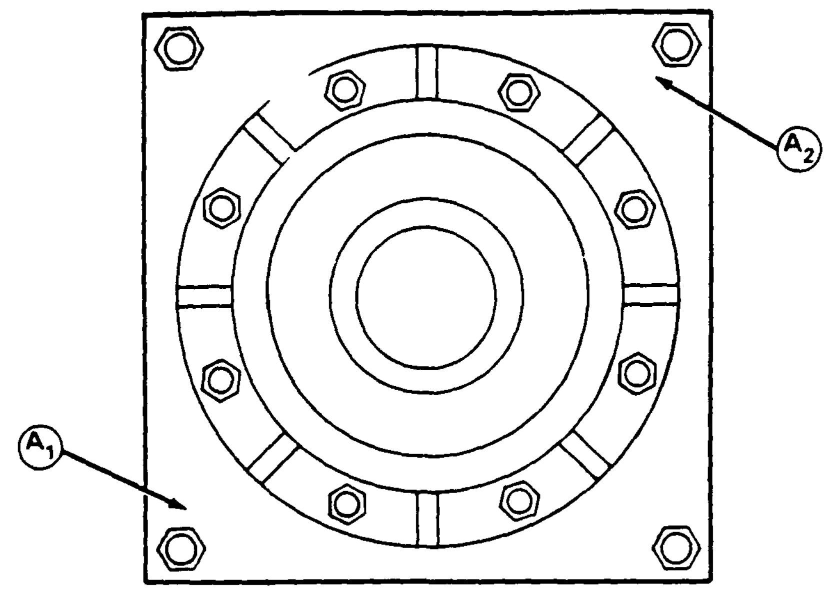


Fig. 3. Triaxial assembly of accelerometers.



MEASUREMENT-POINT LOCATIONS ARE INDICATED BY A_1 AND A_2

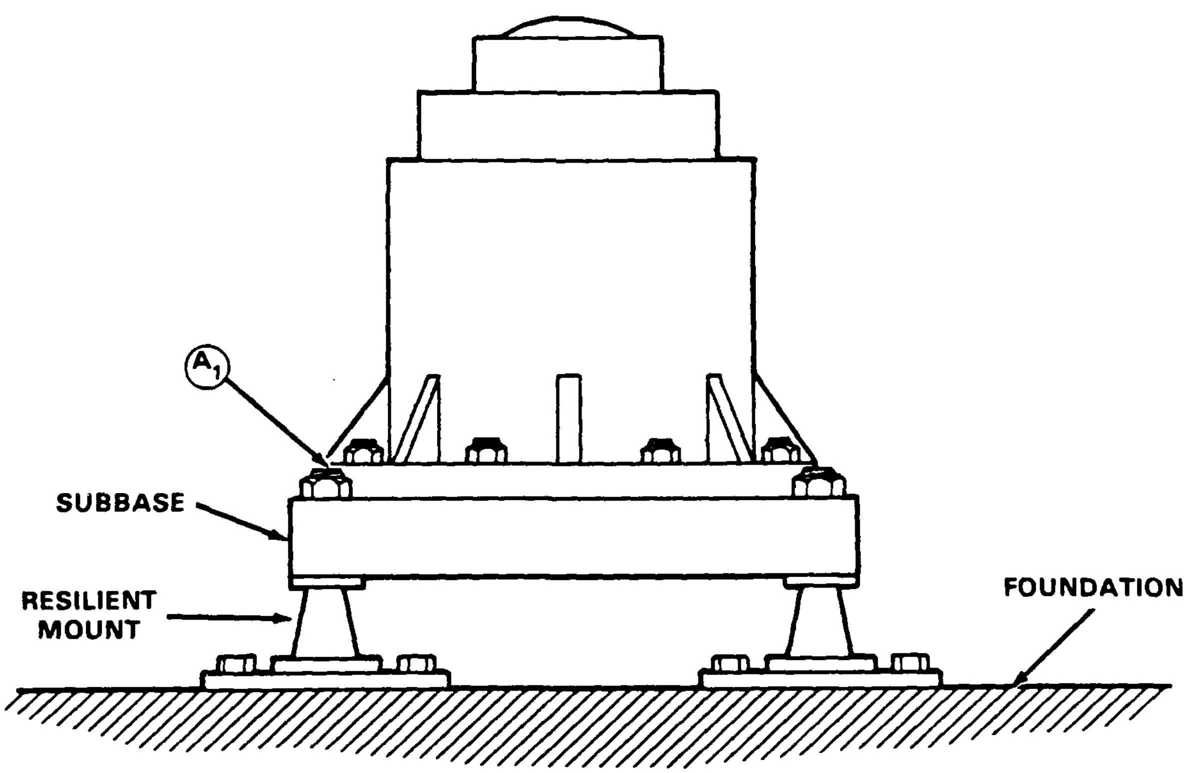


Fig. 4. Example of measurement-point locations on a flanged unit.

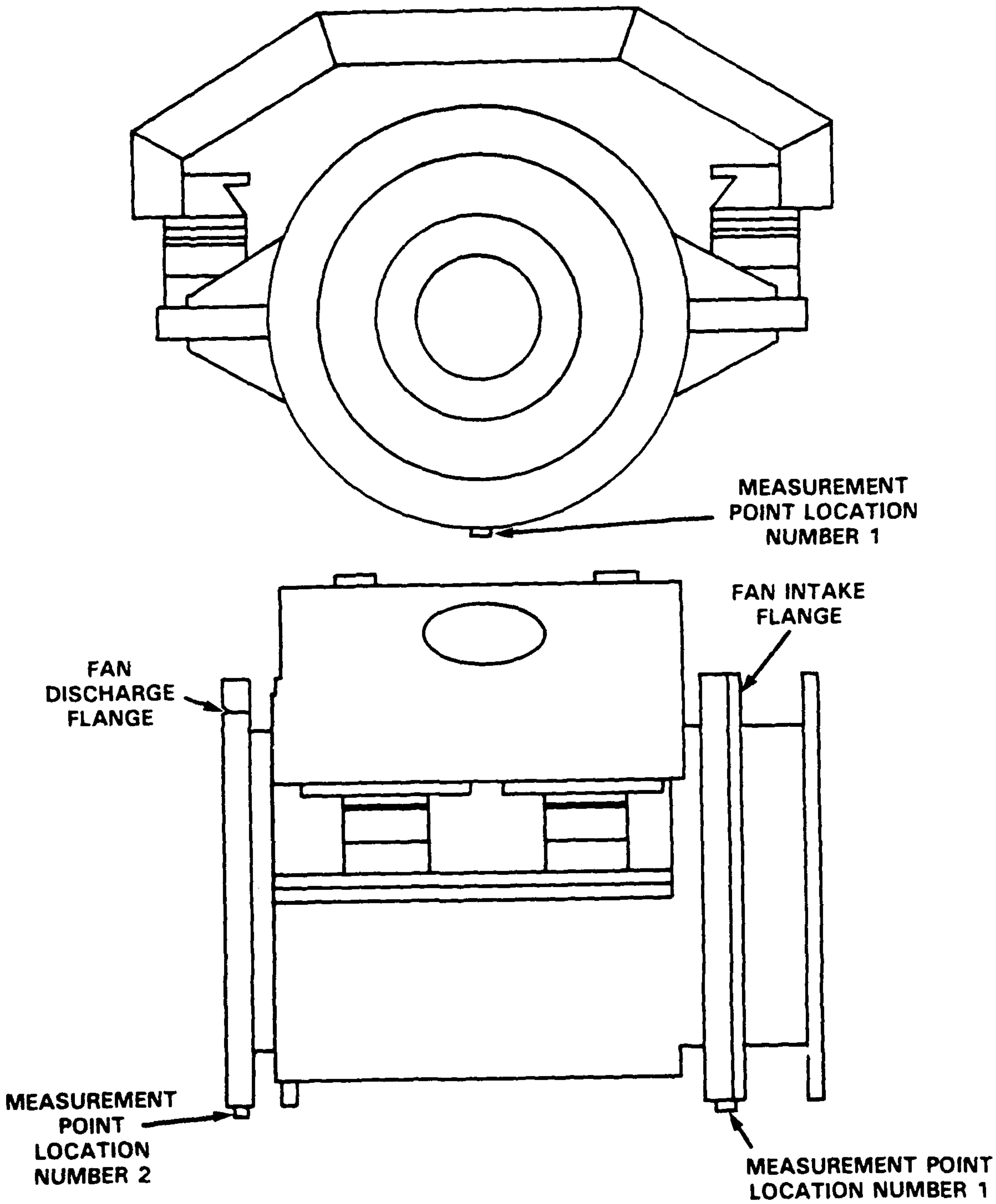


Fig. 5. Vaneaxial fan measurement point locations.

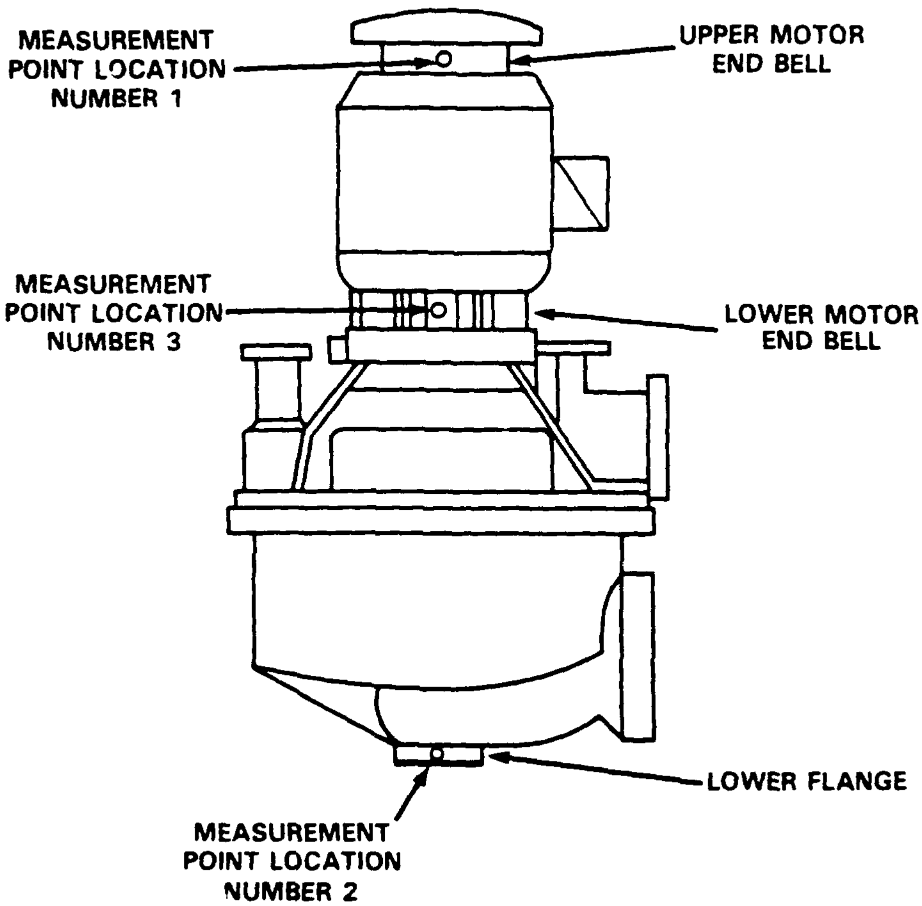


Fig. 6. Motor driven pump measurement point locations.

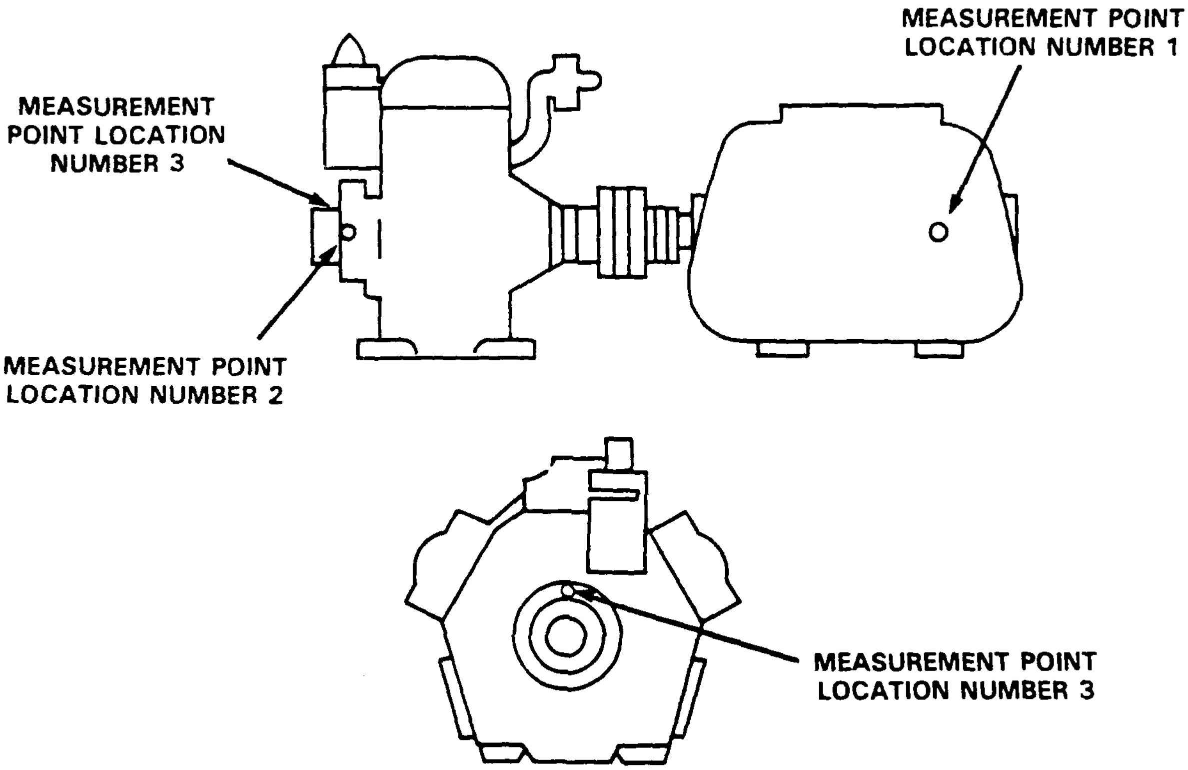


Fig. 7. Motor driven compressors measurement point locations.

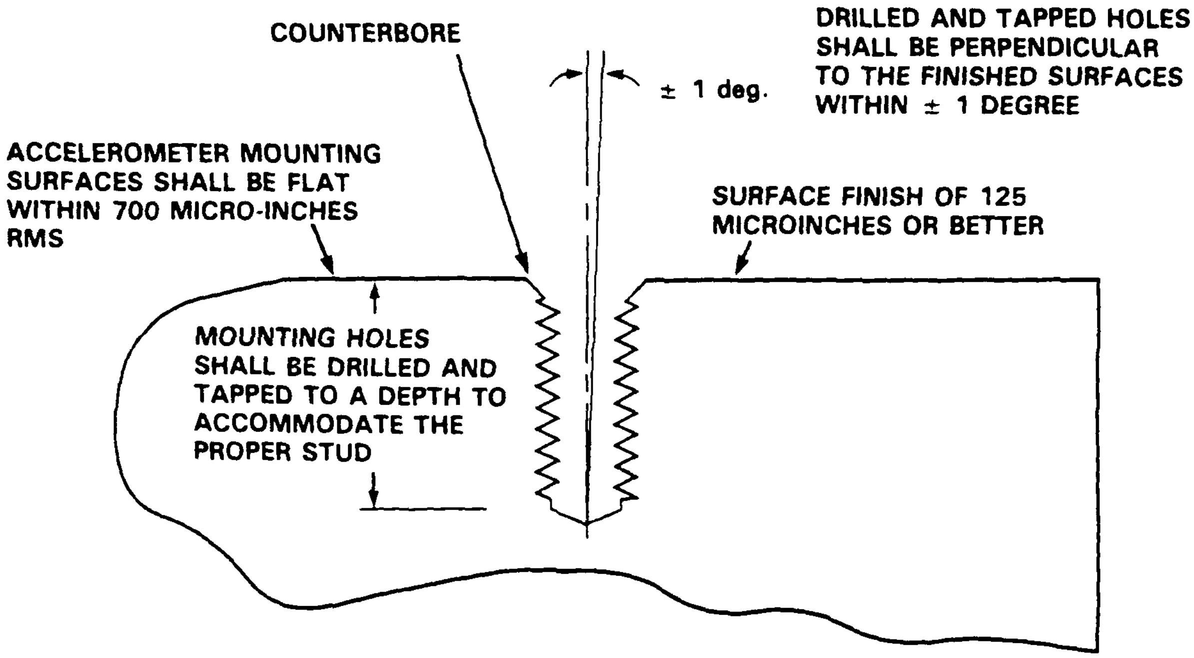


Fig. 8. Surface preparation.

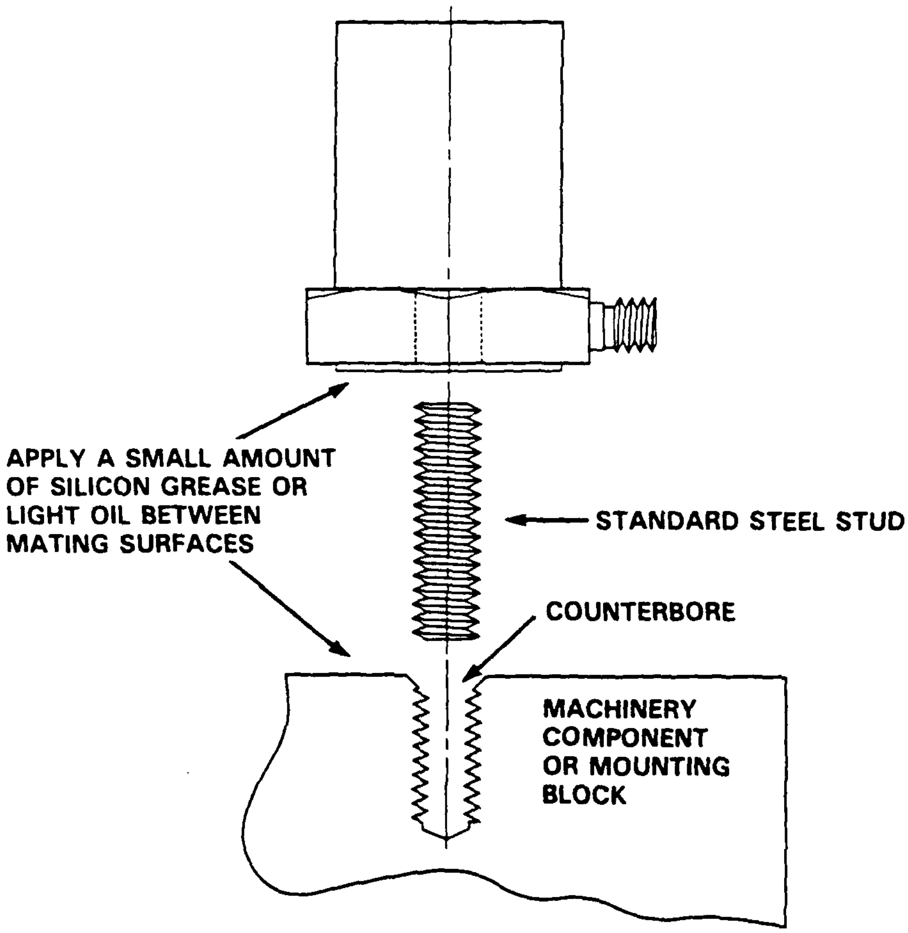


Fig. 9. Preferred method of accelerometer attachment.

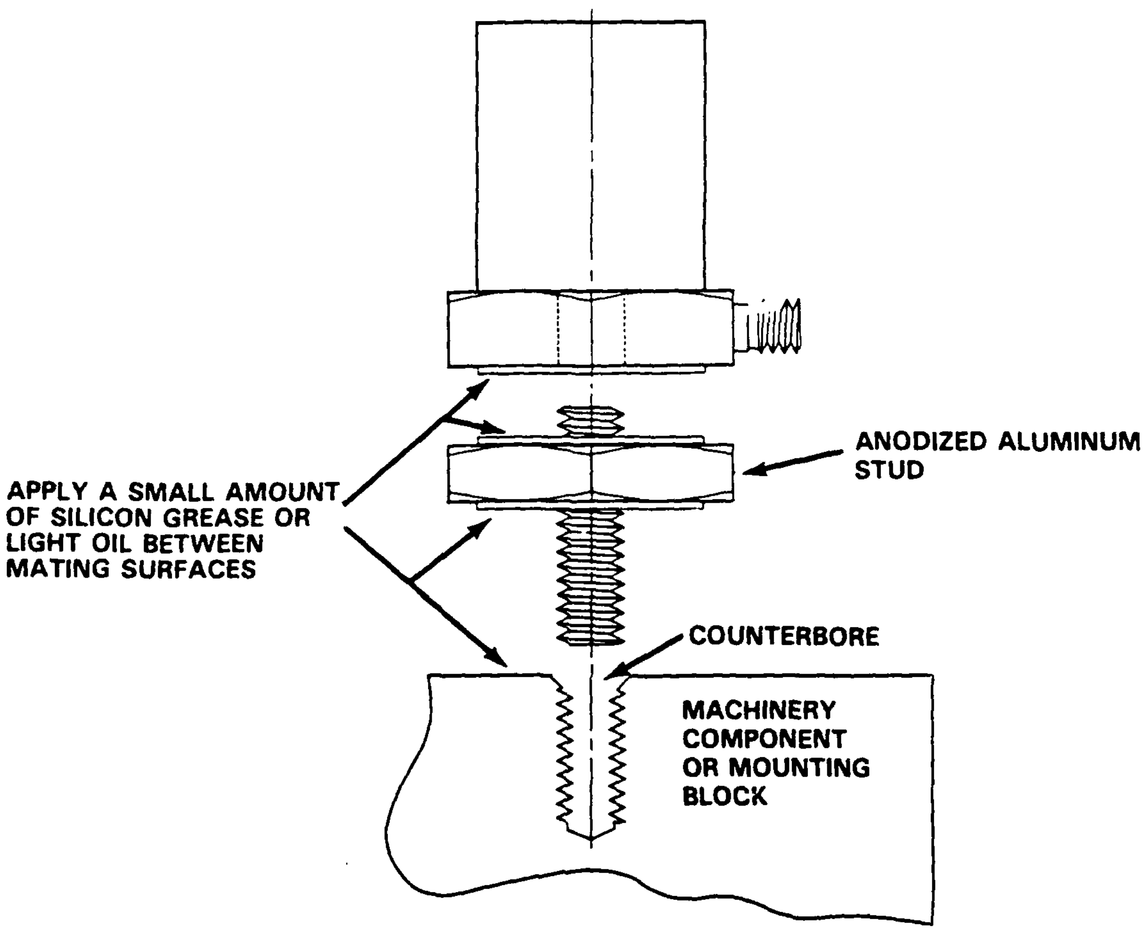


Fig. 10. Anodized aluminum stud used to electrically isolate the accelerometer from the machinery part.

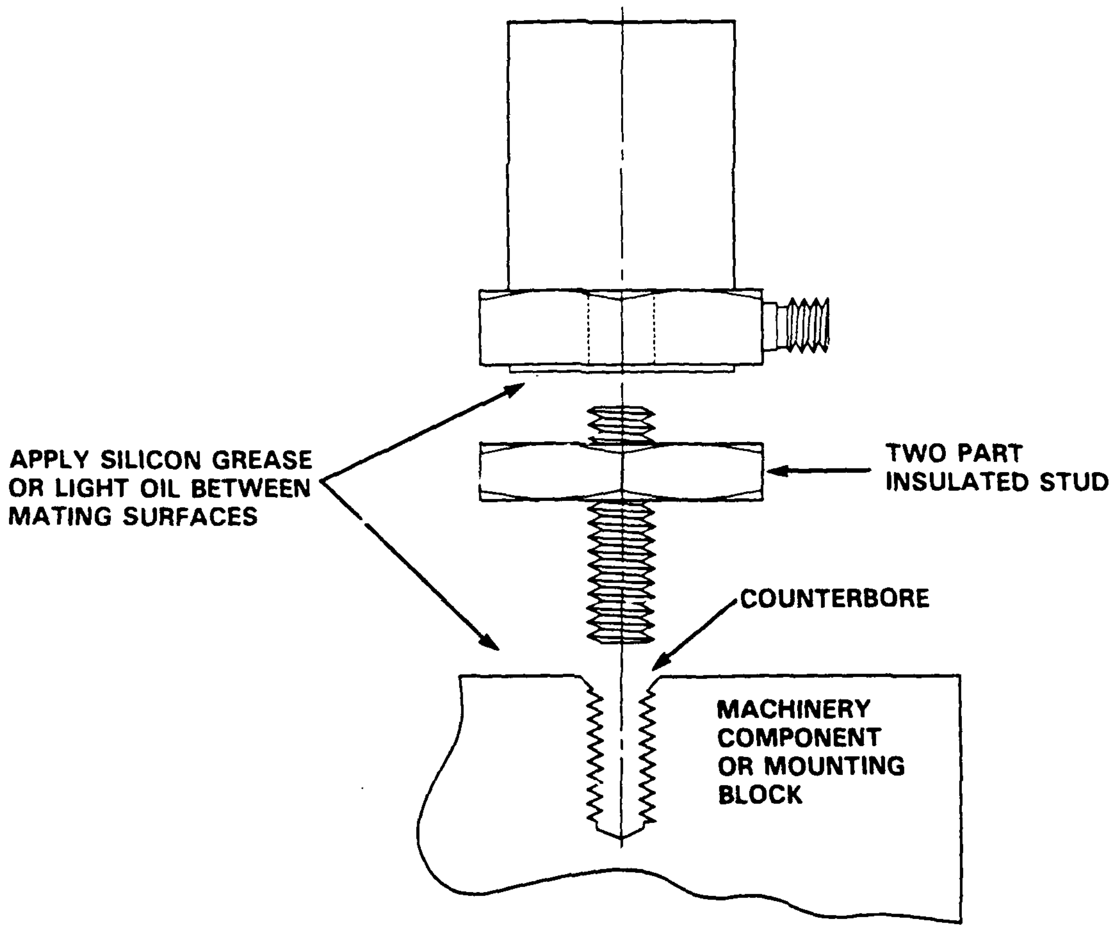


Fig. 11. Stainless steel insulated stud used to electrically isolate the accelerometer from the machinery part.

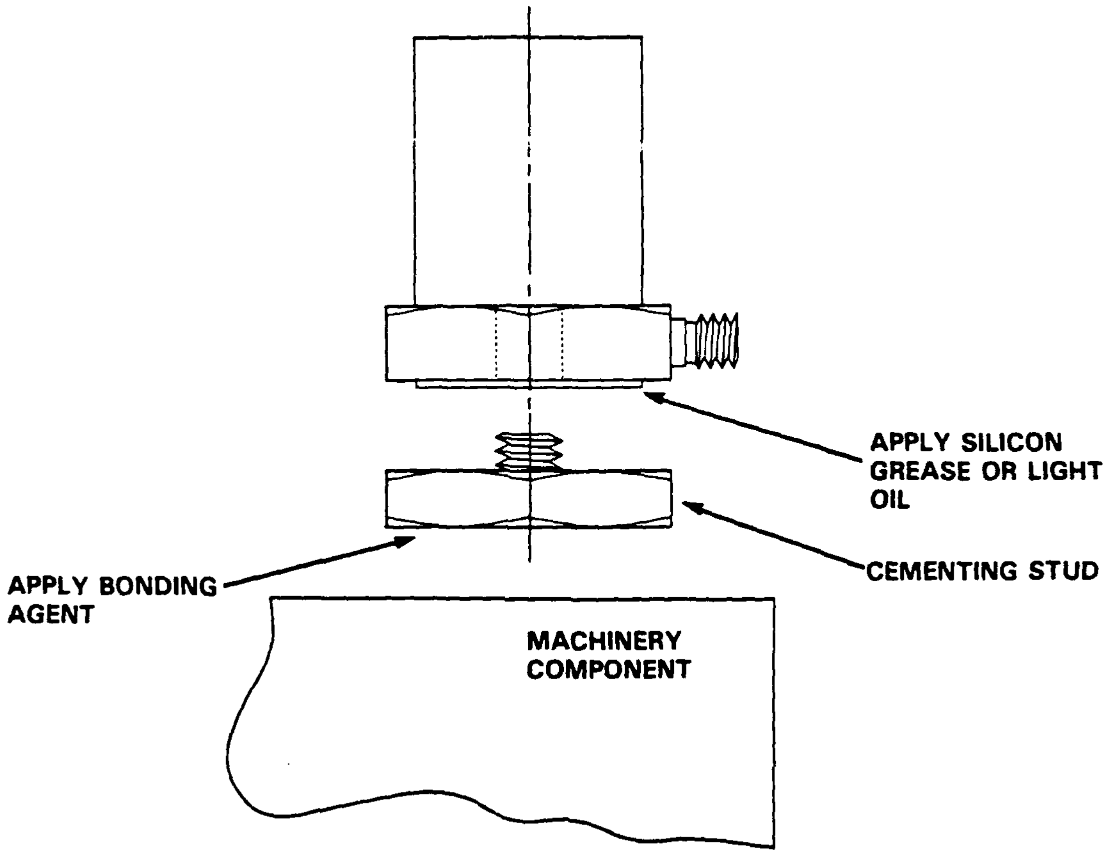


Fig. 12. Anodized aluminum cementing stud used to electrically isolate the accelerometer from the machinery part.

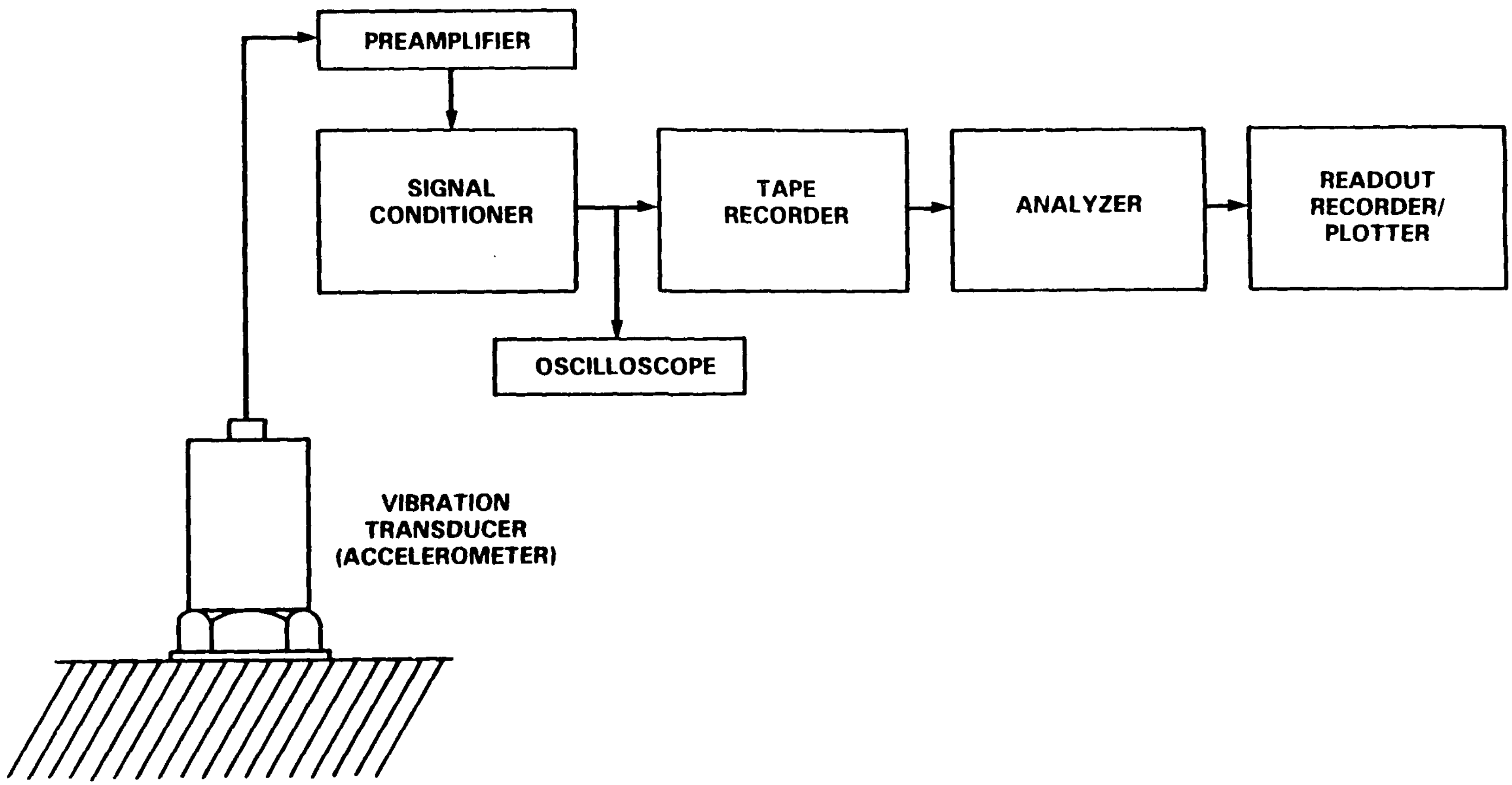


Fig. 13. Vibration measurement system (basic elements).

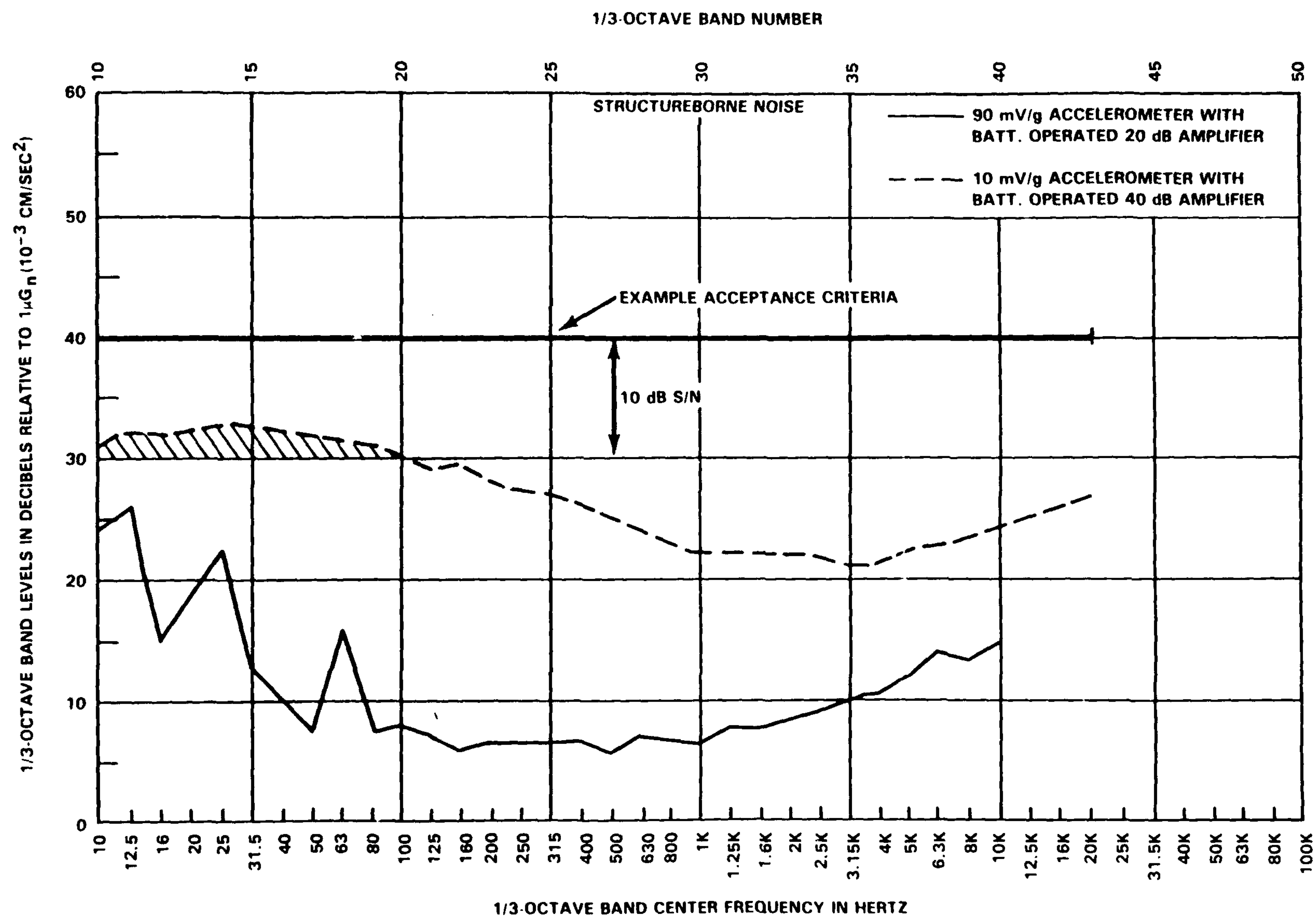


Fig. 14 Accelerometer-preamplifier noise level

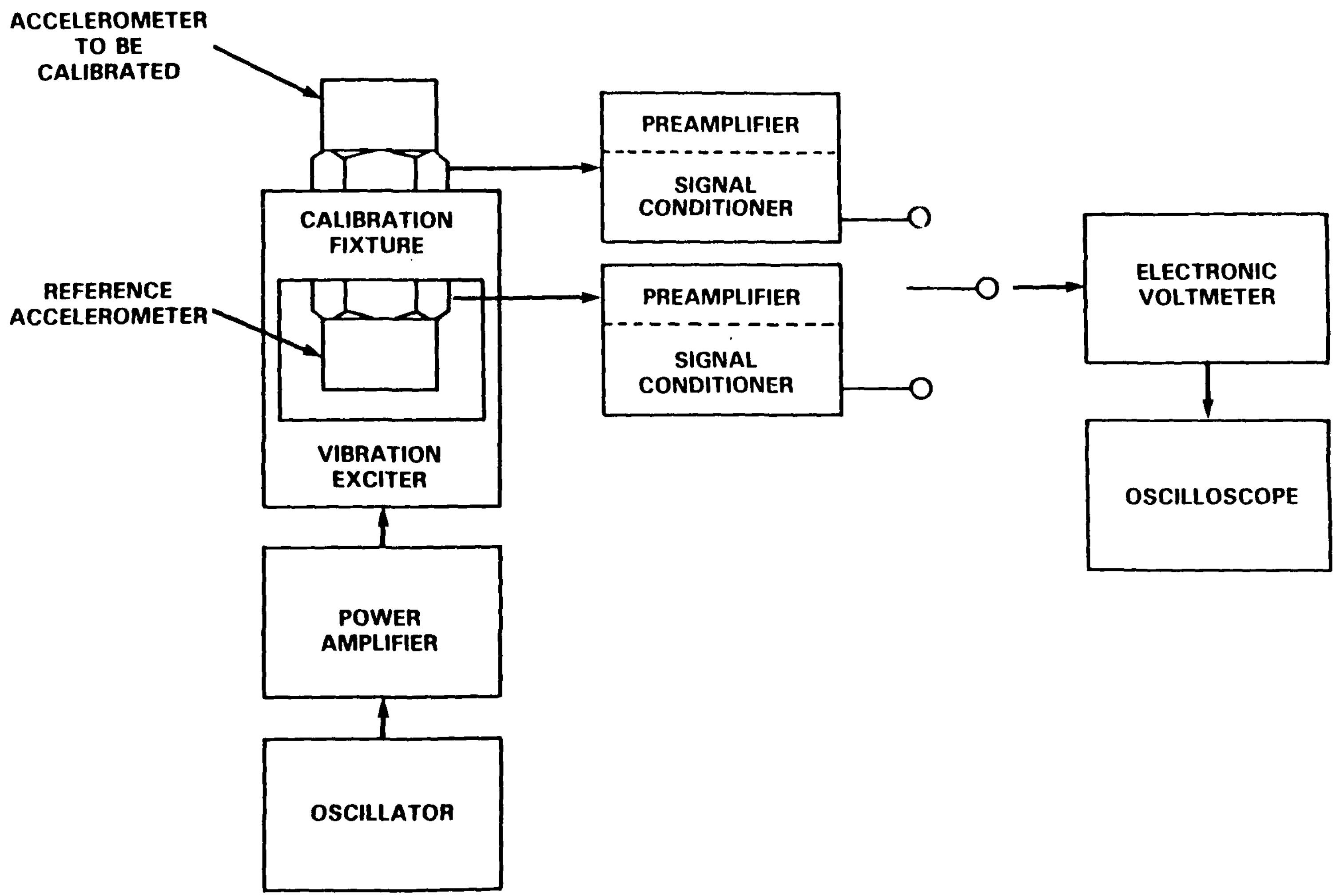


Fig. 15. Comparison calibration of accelerometers.

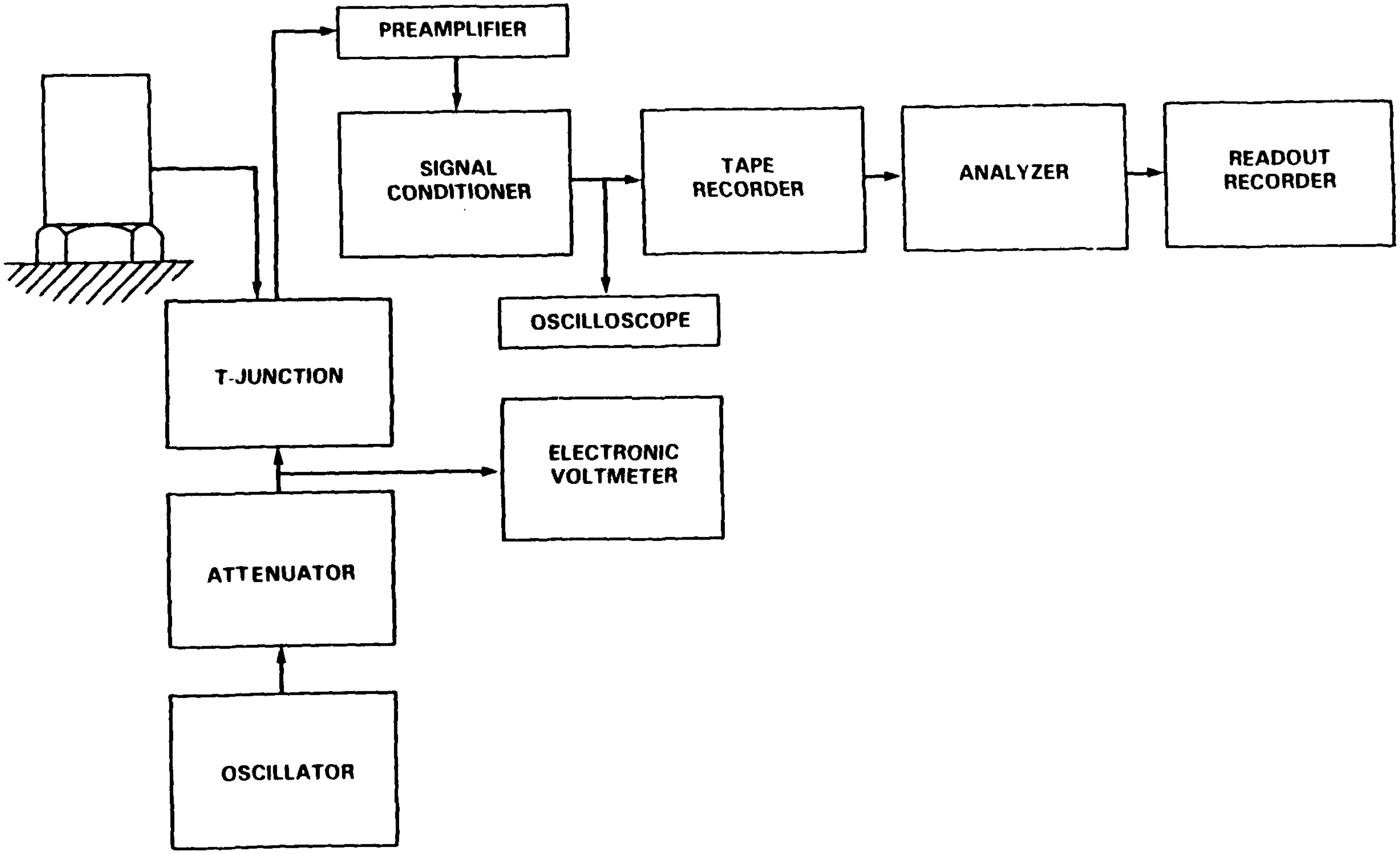


Fig. 16. Electrical calibration.

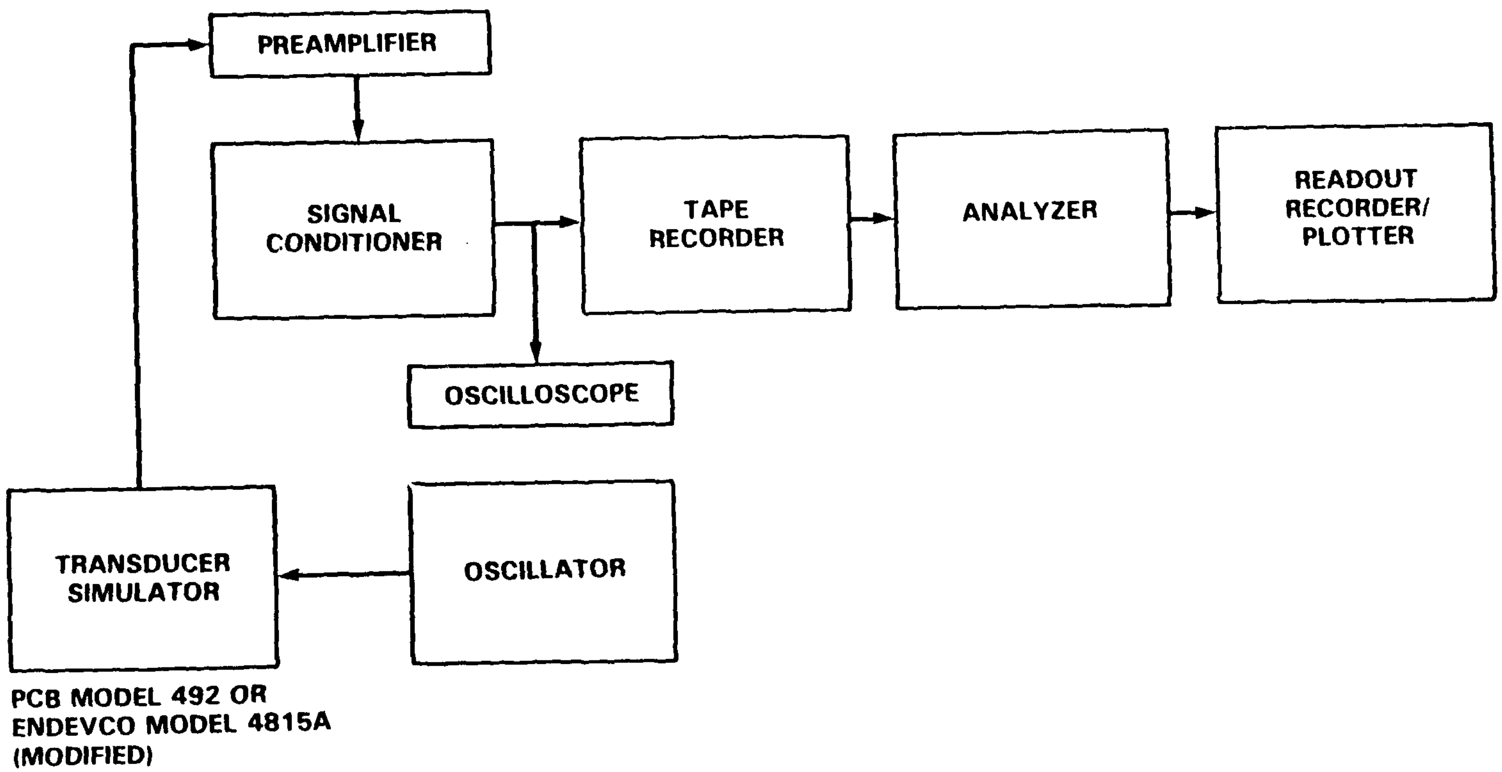


Fig. 17. Laboratory electrical calibration.

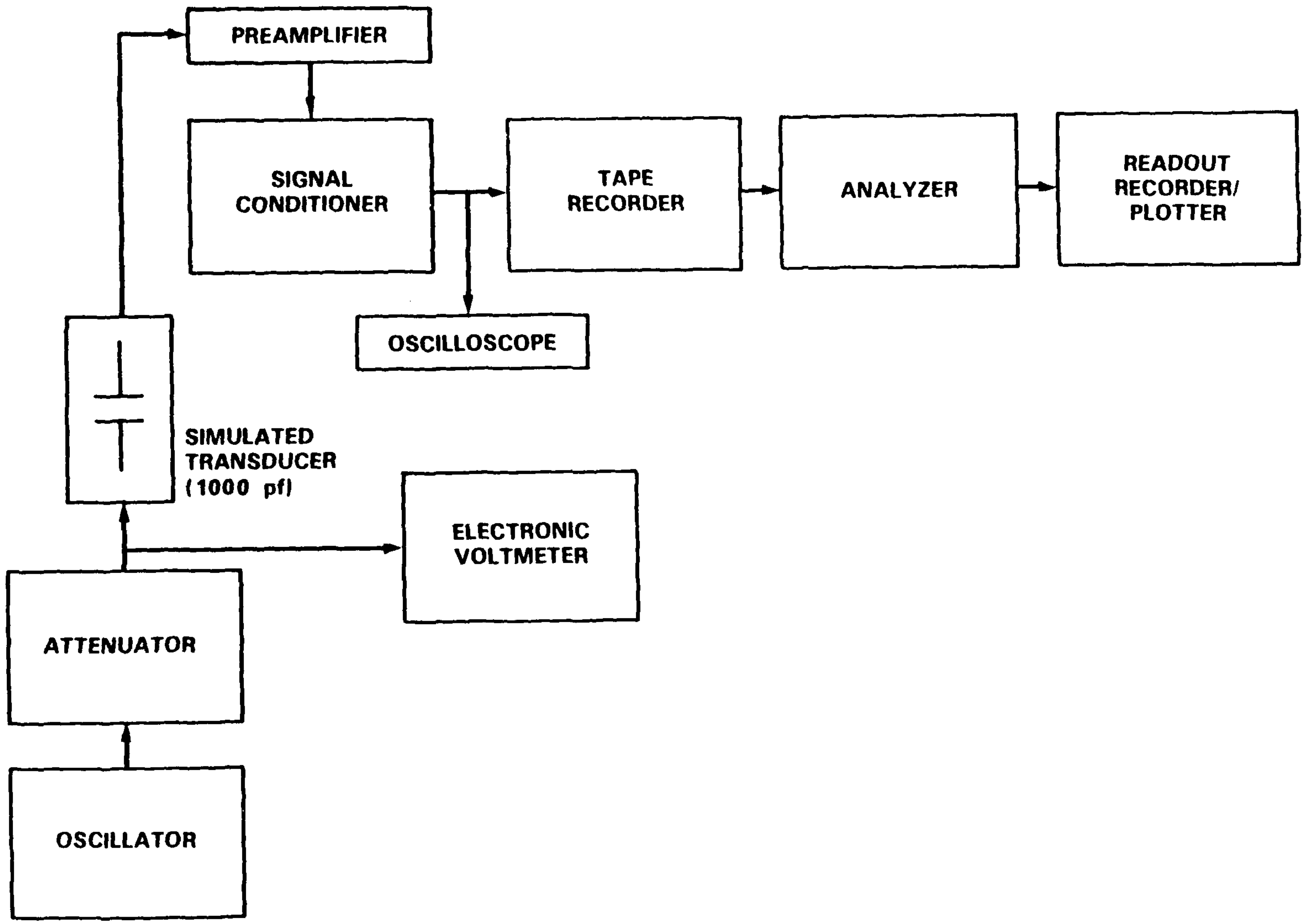


Fig. 18. Laboratory electrical calibration.

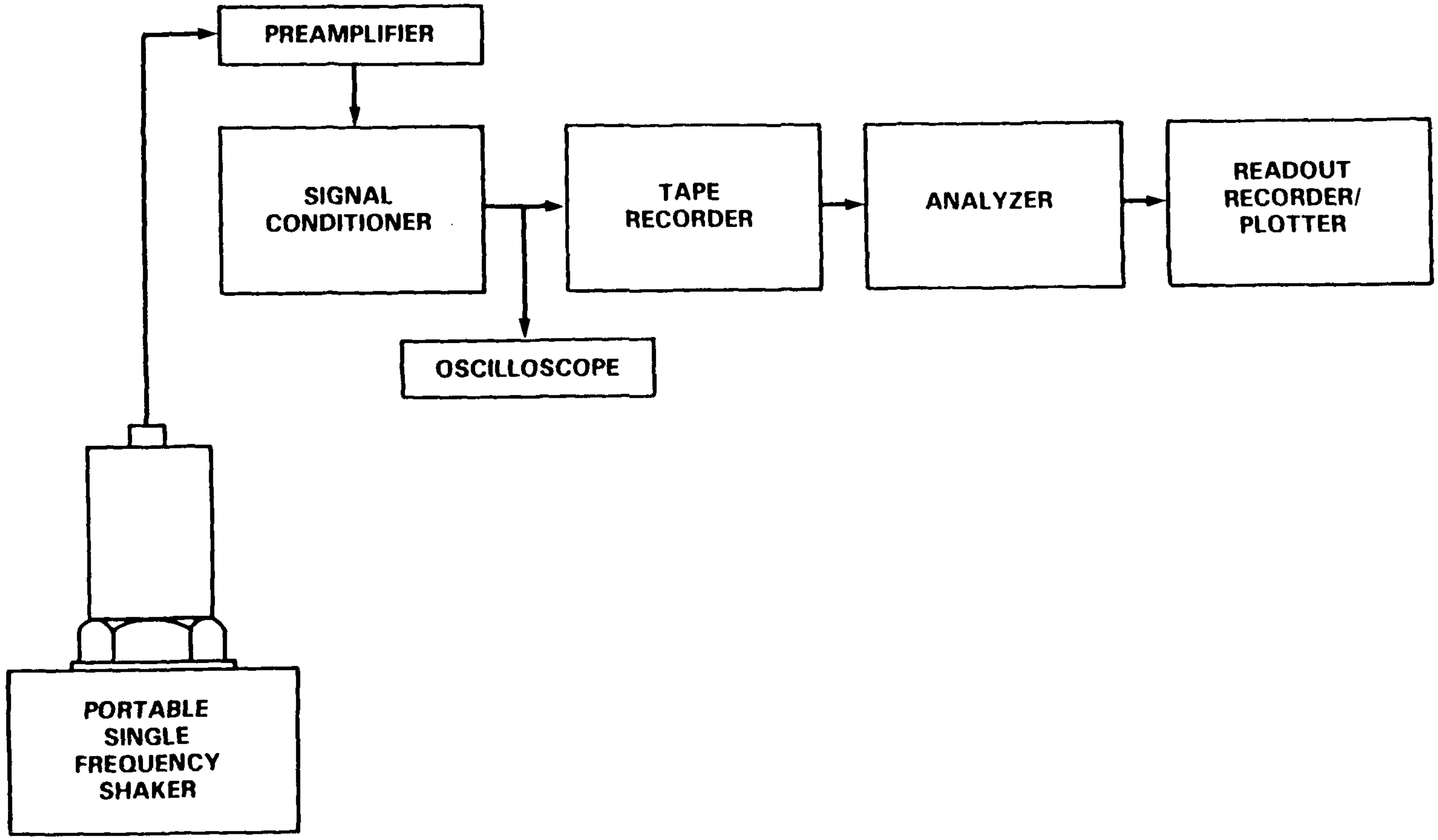


Fig. 19. Mechanical field calibration.

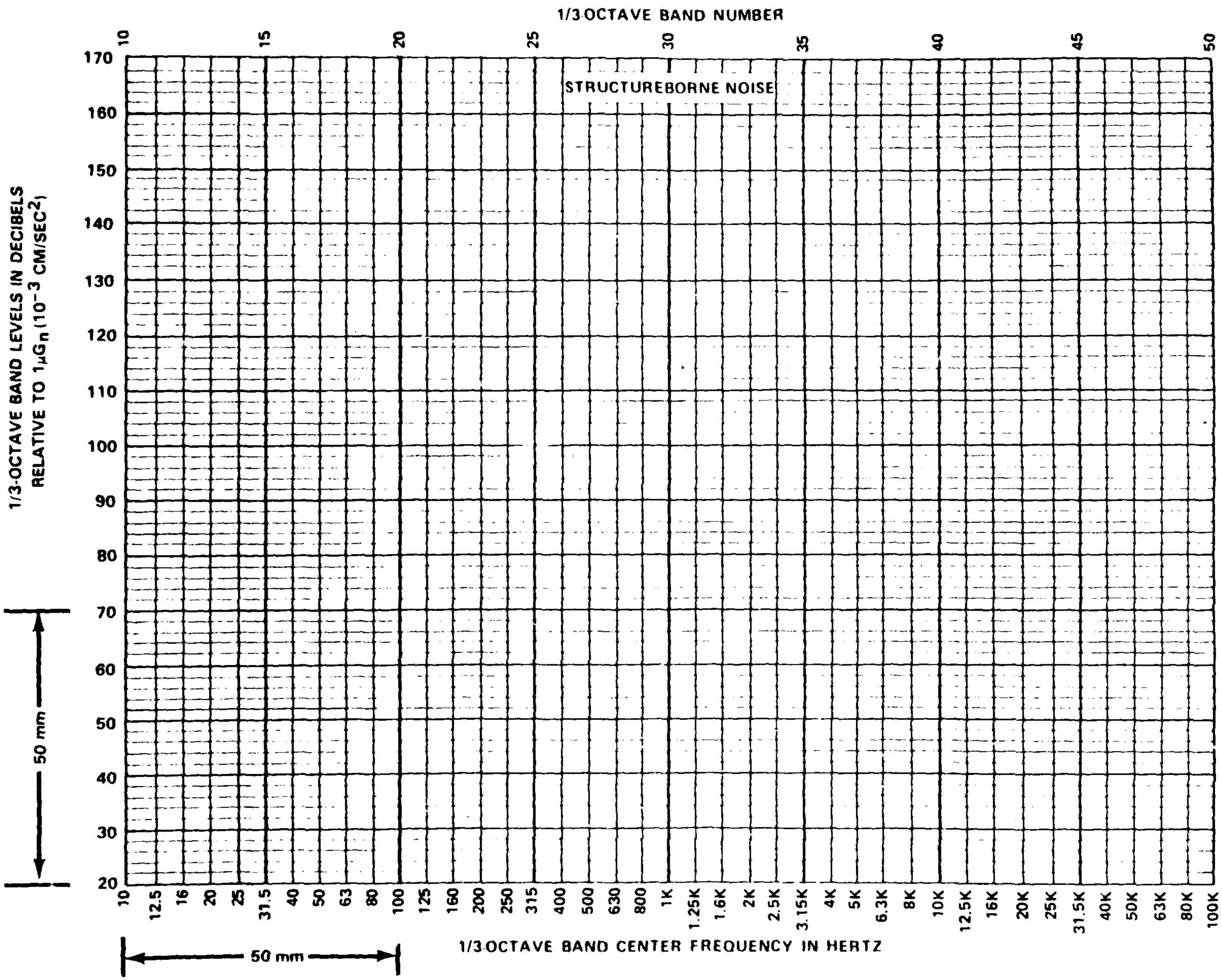


Fig. 20. Example of plotting format for graphs 1/3-octave-band analysis.

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